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Production and characterization of bacterial cellulose fabrics

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Introduction

Plant cellulose (such as cotton, flax, and wood pulp) has long been utilized to produce textile materials. The hydrophilicity, soft hand, medium to high strength and durability, biodegradability, and easy coloration make these cellulosic materials good choices for consumer textile products. With the increasing consumption of textiles due to population growth and living standard improvement, the burden on growing these cellulose containing plants on diminishing lands has been escalating, which resulted in higher material price. The environmental impacts of growing the plants (e.g., fertilizer and pesticides, soil erosion and desertification, and water use in irrigation) and from manufacturing the cellulose into textiles (e.g., chemicals used to remove lignin and hemicellulose, water and energy use) are receiving more concerns. Therefore, people are looking for alternative materials. Bacterial cellulose (BC) is one such material that has drawn attention in recent years. BC is extracellular cellulose synthesized by a class of acetic acid producing bacteria from monosaccharides, disaccharides, and alcohols in aqueous media (Hu et al., 2014; Shah et al., 2013). Glucose chains are produced inside the bacterial body during fermentation processes and then being extruded out of the body. The chains combine and form cellulosic nanofibers. A nanofiber nonwoven web is then generated from these nanofibers on the surface of the media. BC fibers have high purity, high crystallinity, and high degree of polymerization which impart BC high tensile strength (especially wet tensile strength), high water holding capacity, and slow water evaporation rate. The porous nonwoven web structure provides the material large surface area which increases the ability of chemical modifications. Furthermore, the material is biodegradable, biocompatible, fast to produce, and three-dimensionally moldable. BC has been researched for possible applications for food, biomedical, and biotechnology. Although textiles are mentioned as potential applications of BC (Çakar et al., 2014), the authors have not seen any published research studying the various properties that are critical to textile products such as apparel and footwear. The purpose of this study was to investigate the possibility of using BC nonwoven as textile fabrics to make consumer products. The objectives were: 1) to study the influences of fermentation conditions on the production of BC fabric; 2) to investigate the physical and mechanical properties of BC nonwovens (thickness, weight, tensile strength, tearing strength, and stiffness); and 3) to study the possibility of producing inherently colored BC nonwovens.

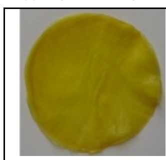
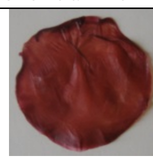
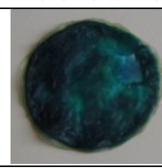
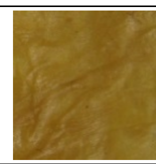
Materials and Testing

BC Fabric Production: Symbiotic culture of bacteria and yeast (SCOBY) containing Acetobacter, vinegar, cane sugar, and tea were used to prepare the aqueous bath. The fermentation was taken place in an oven at 23°C. For objective 1, parameters studied included sugar concentration in the bath (10% and 20% by weight), tea type (black, green, and red), and fermentation duration (1 week, 2 weeks, 3 weeks, and 4 weeks). For objective 2, to study the various fabric properties, 20% sugar concentration and black tea were used and the fermentation was at 23°C for 2 and 4 weeks. For objective 3, one of the various dyes (natural dyes including turmeric, saffron, and beet; artificial colors including red, orange, yellow, green, blue, and violet) was added to the bath prepared with 10% sugar concentration and green tea and the fermentation was at 23°C for 3 weeks. All the fabrics were dried at ambient conditions (21±1°C and 30±2% RH) for at least 4 days before testing.

Testing: For thickness, weight, tensile strength and elongation, tearing strength, and stiffness, the Digital Micrometer M121 (5 replications), Denver Instrument Scale (3 replications), Instron 5565A (test method: ASTM D5035-11), Elmatear² Digital Tear Tester 855 (test method: ASTM D1424-09), and Gurley 4171D Digital Stiffness Tester (3 replications) were used respectively. The test was completed under 21±1°C and 30±2% RH.

Results and Discussion

The results showed that BC fabrics could be produced with all three types of tea, i.e. black, green, and red, and the two sugar concentrations. A very thin layer of transparent fabric could be seen on the top of the aqueous bath within around one week. With fermentation duration increased, the fabric thickness increased and the transparency decreased. The fabric color produced by black tea was light brown color, while by green tea was no color and by red tea was a pale pink color. When applied 20% sugar concentration, the fabric grew faster and the final thickness was larger than the 10% sugar concentration. After dyes were added to the fermentation bath, all natural dyes and the blue artificial dye supported fabric growth and colors were successfully incorporated into the fabric. With addition of the rest of artificial dyes, fabric growth was inhibited. Pictures of colored fabrics are shown below.

					
Turmeric	Saffron	Beet	Blue	Black Tea	Red Tea

The physical and mechanical properties of fabrics produced with 20% sugar concentration, black tea for 2 and 3 weeks were shown in the table below. The tensile strength and elongation of BC fabrics were higher compared to most consumer used nonwoven fabrics while the tearing strength and stiffness of BC fabrics were similar to that of commonly used nonwoven fabrics. The weight was heavy due to the high water content in the fabric.

	Weight (g/m^2)	Thickness (mm)	Tensile Load (N)	Elongation (%)	Tearing Strength (N)	Stiffness (mg)
2 weeks	726.3 ± 50.0	0.53 ± 0.04	113.4 ± 30.2	23.0 ± 8.8	3.01 ± 0.6	122.8 ± 20.3
3 weeks	840.8 ± 102.0	0.73 ± 0.1	199.2 ± 69.9	27.1 ± 11.1	5.49 ± 2.5	133.7 ± 11.7

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